Lab 6, part two: Structural geology (analysis)

Recall that the objective of this lab is to describe the geologic structures of Cougar Mountain Regional Park. In the first part, you obtained structural (attitude) data for geologic formations (mappable units of rock) of that area.

Write three working hypotheses of how Cougar Mountain came to be. In other words, suggest three ways in which Cougar Mountain could have formed, given the data you have already collected.

By performing the analysis, as well as getting some background information, you will be able to infer the most consistent hypothesis by the end of this lab.
As you have seen from the “Dating Methods” lab, most geological processes take place over thousands or millions of years and so have very little direct effect on our lives. In future labs, you will explore the more sudden (and catastrophic) geological events, such as earthquakes and landslides. In this lab, you will see how to use the results (hidden in the rock record) of many sudden events to reconstruct geologic history. Part of this analysis is structural geology.

**Stress and Strain**

Tectonic forces move and deform the Earth’s lithosphere. These movements create stress in the lithosphere, which is measured in units of force (such as Newtons, or N). In turn, the rocks accommodate the stress by changing the space they occupy. This change in size is called strain, which is measured in units of volume (such as meters-cubed, or m³).

There are three basic types of stress: compression, extension, and shear.

- **Compression** results in rocks (as small as a layer and as large as a plate) being pushed together
- **Extension** (or tension) results in rocks being pulled apart
- **Shear** results in rocks sliding past one another

Regardless of the type of stress, the amount of stress can result in different strain response by the rocks: elastic deformation, plastic deformation and brittle failure.

- With a small amount of stress, the deformed rock returns to its original shape after the stress is removed. This is **elastic deformation**. A good example of this is **isostatic rebound**, when an area, which had been under a thick continental ice sheet, returns to its original elevation after the ice sheet has melted.

- With a bit more stress, the deformed rock rebounds somewhat when the stress is removed, but some permanent strain remains. This is **plastic strain** (the word “plastic” refers to the moldable property of the rock—hardly an everyday experience!). **Folds** are examples of plastic strain in a large volume of rock.

- After a lot of stress, the deformed rock will fracture or break, and the rock’s volume does not return at all to its original size. This is **brittle failure**. A **fault** is an example of brittle failure in a large volume of rock.

1. What sort of rocks will structural geology be most effective on (recall the emphasis on layers)? Indicate your answer by circling the most appropriate rock types.

   Intrusive igneous  Extrusive igneous  Clastic sedimentary
   “Other sedimentary”  Foliated metamorphic  Non-foliated metam.
Folds
Folds are warped or bent layers of rock, usually consisting of two limbs dipping (tilting) in opposite directions. In simple folds, the axial plane is the surface that passes through the points of maximum curvature of the fold. The expression of the axial plane on the surface of the land is the fold axis (or hinge line), which is usually a straight line. See the diagram below.

There are two fold types: anticlines, in which the strata (layers) dip away from the fold axis; and synclines, in which the strata dip towards the fold axis. Note the terms anticline and syncline do not necessarily refer to landforms such as hills and valleys; rather, the terms describe the cross-sectional appearance of the rock layers (remember that erosion will alter the topography at the surface!). Thus, geologists can recognize an eroded syncline or anticline, even if the surface is eroded flat, by observing the orientation and relative ages of the strata.
2. a. Put **attitude symbols** (the little “T”s — don’t worry about the exact dip angle) on the **top surface** of the two block diagrams below.

![Block Diagrams](image)

b. Which numbered layer corresponds to the oldest rock unit of the anticline?

c. Which numbered layer corresponds to the youngest rock unit of the anticline?

d. Which numbered layer corresponds to the oldest rock unit of the syncline?

e. Which numbered layer corresponds to the youngest rock unit of the syncline?

The fold axis can also be tilted, leading to **plunging** folds. When planed off by erosion, as shown in the diagram, the fold pattern on the ground can look odd, but still allow the reconstruction of the eroded fold.

![Fold Diagram](image)

3. Complete the blank side of each of the two block diagrams by filling in the layers that should be visible; use the existing patterns to indicate layer types.

![Blank Block Diagrams](image)
Faults
Faults are breaks or fractures in rocks along which movement of one side relative to the other has occurred. Breaks or fractures in rocks which exhibit no relative motion are called joints. While the expression of a fault (such as the San Andreas Fault in California or the Straight Creek Fault near Marblemount) on the surface is usually linear, the actual break or fracture is a planar surface, called (not shockingly) a fault plane.

The hanging wall of a fault rests on or lies above the fault plane; the footwall supports the hanging wall and is therefore underneath the fault plane. Note that this terminology does not necessarily make sense for every type of fault.

The upthrown block (or overriding plate) is the side that moves upward relative to the other side and the downthrown block is the side that moves downward. Once again, this terminology does not necessarily make sense for every type of fault. Note also that the footwall is not always the upthrown block, as shown in the diagram.

The slip is the distance measured along the fault plane that one side of the fault has moved relative to the other. There can be vertical and horizontal components to the slip. The slip rate is the slip divided by the time interval. Faults are classified according to their relative movement, which can be up/down, right/left or a combination.

• In normal faults, the hanging wall moves down relative to the footwall. It is called “normal” because the superposition rule is preserved: younger rocks remain above older rocks.
• In reverse faults, the footwall moves down relative to the hanging wall. It is called “reverse” because the superposition rule is reversed: older rocks end up above younger rocks.
• In strike-slip faults, the fault plane is nearly perpendicular (at right angles) to the surface and any slip along the fault is parallel to the orientation (strike) of the fault plane. The strike-slip fault shown in the accompanying diagram is called a left-lateral strike-slip fault because the motion on the opposite side of the fault (from your perspective) is to the left. The opposite motion would be called right-lateral.
4. Fill in the table below (recall that the types of plate boundaries are convergent, divergent and transform):

<table>
<thead>
<tr>
<th>Fault type</th>
<th>Associated type of stress</th>
<th>Associated type of plate boundary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reverse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strike-slip</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. For the cross-section below, draw the map view of the area above. Don't forget to indicate where the fault is and label each side of the fault "U" or "D" to indicate up and down directions of motion.
6. For the **map view** of the strike-slip fault below, draw the **cross-section** that corresponds to a slice taken along the line A-A'.

7. Plot the attitude symbols for the stops of the Cougar Mountain field trip at the appropriate spots on the map, using the GPS coordinates that you obtained. Make sure that the spots you plot seem to be *consistent* with the roads that are shown!

8. Given your attitude symbols and the formations mapped as shown, and given that there is a simple structure in this area, plot one of the following:

   • If you believe there is a **fault** in this area, draw a line that shows the **trace** of the fault at the surface, and use either arrows or the U/D notation to indicate relative motion along the fault. See the symbols below.

   • If you believe there is **fold** in this area, draw a line that represents the **fold axis**. The fold axis should be parallel to the contacts between the formations, as shown by the dotted line in question 2a. See the symbols below.

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**A local use of structural geology**

The next page is a **geologic map** of Cougar Mountain, between Renton and Issaquah.

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**attitude syncline anticline thrust fault strike slip fault**
On the next page is a cross-section of the same area. The line A-A’ on the geological map above is the line along which the cross-section is drawn (pretend that we can dig a trench miles deep along that line; the cross-section is what the wall of the trench would look like). The top of the cross-section is called the topographic profile and represents the altitude of the land surface.
9. Complete the cross-section of Cougar Mountain. Make sure to shade in the different formations with different colors or patterns.
10. a. Using the map and cross-section, what is the **oldest** formation in the Cougar Mountain area?

b. What is the **youngest** formation in the Cougar Mountain area?

11. **Analysis**:

a. What is the **simple structure** in the Cougar Mountain area? Add a phrase like “...whose axis trends (east-west/north-south)” to describe its orientation.

b. From part a, what can you infer about the **type** of stress (compressive/extensive/shearing) and the **orientation** of the stress (east-west/north-south)?

c. The rocks of the Cougar Mountain area are dated as between 30 to 40 million years old. If the dating method used was **potassium-argon radiometric dating**, what material that you saw on the field trip could be appropriately dated by that method?

12. **Conclusion**:

a. As you know, there is a subduction zone off the Washington coast. Given the orientation of that subduction zone (north-south), is the type of stress that made Cougar Mountain **consistent** with the type of stress generated by a subduction zone? Is the orientation of the stress that made Cougar Mountain **consistent** with the orientation of the stress of this subduction zone?

b. Was the **timing** of the stress that generated Cougar Mountain before, after or at the same time as the timing of the subduction zone stress? Or is it even possible to infer such relative timing? In any case, **explain** your conclusion.
c. Finally, now that you have some data on these rocks, what other information would be helpful in answering part b more definitively? In other words, would more attitude measurements of these formations be useful? If so, where, and what might you expect?

Examples of stress on rocks

13. a. Examine ST-1, which is a rhyolitic tuff (light-colored layers) sandwiched in obsidian (this rock was found in Monida Pass, Idaho). What event generates a tuff?

b. Does tuff therefore follow the law of original horizontality?

c. So, what kind of stress (compressive, extensive or shearing) is evident in the rock?

d. Was this a sudden or gradual stress? How can you tell?

e. How can you tell that this rock was solid when the stress was applied? In other words, if the rock were even partially molten, what differences would you notice?

14. a. Examine ST-2, which is a from Matillija Canyon near Ojai, California. The smooth surface is called a slickenside. Is this the result of compressive, extensive or shearing stress (hint: more than one answer is possible)?

b. Along what type of structure (fault or fold) would a slickenside be found?
15. a. Examine the marked side of ST-3, which is a siltstone from Knappton, Washington. What type of structure is evident on that side?

b. Stratigraphic “up” is marked by the arrow on the rock. Sketch the face oriented vertically, and indicate any motion recorded in the rock by arrows.

c. These type of structures are called listric, because they flatten out as they go down. These structures exist under the Los Angeles Basin and are responsible for many of the non-San Andreas Fault earthquakes. Please classify this structure using one of the words in the left column of the table in question 7.